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ELECTRO-SURGERY*

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AT the present day, when describing the use of electricity in surgical procedures, reference in almost every instance implies the employment of high frequency electrical currents which may have different characteristics such as the damped wave produced by means of a high frequency electrical apparatus having a spark gap in circuit and the undamped wave which we get from a high frequency apparatus having radio tubes in its circuit.

Tissue may be separated or cut through by a current from a high frequency apparatus in which the oscillating circuits are so balanced that a wave which is not more than 20% damped is produced, or for the same purpose we may use the undamped wave high frequency current giving a constant and steady heat effect which will quickly cut its way through, an ordinary needle serving as the active electrode. This electrical action has been described by various writers using many different names, some of which are very suggestive of commercialism, conveying no expression of the particular procedure involved.

Many times attention has been called to the importance of avoiding a duplication of terms used in describing electrical current effects or methods of treatment, as this results in much confusion of ideas. And once more a plea is made, as first alluded to by the writer about ten years ago, for the more general use of the term "electro-surgery" which comprises the use of electricity in its many forms for the destruction or removal of body tissue.

Dr. Harvey Cushing, Professor of Surgery in Harvard University stresses this point in the following quotation from an extremely valuable contribution to the annals of surgery of the subject of "Meningiomas Arising from the Olfactory Groove and their Removal by the Aid of Electro-Surgery" published in *The Lancet*, of London, England, June the 25th, 1927: "Since, by the employment of a small ("active") electrode and a large ("indifferent") electrode, all the cutting effects can be confined to the tissues in the immediate vicinity of the active electrode, it constitutes a surgical tool which bids fair to replace the scalpel in certain fields of work.

Naturally enough, following Pozzi's lead, this new adjunct to surgery has for obvious reasons been chiefly restricted to the removal of malignant growths and has, therefore, remained largely in the hands of specialists who are called upon to treat malignant disease in inaccessible places. Those who have seriously employed these methods in the extirpation of carcinoma about the mouth and other body orifices have written enthusi-

*Read at the Annual Meeting of the Vermont State Medical Society at Middlebury, October 14, 1927.

astically on the subject. But meanwhile, owing to the variety of trade names which have been introduced, no little confusion has arisen as to the meaning of fulguration, diathermy, endothermy, and so on. No less has there been confusion in regard to the various forms of current that are employed, whether unipolar or bipolar, whether for cutting, dehydration, or coagulation. For purposes of simplification, therefore, it would seem better for the time being to utilize the single term of "electro-surgery" for all these varied performances."

Electro-surgery has a distinctive place in the field of general as well as special surgical endeavor, as it may be used with safety and bring satisfactory results in the treatment of many conditions heretofore dangerous and inaccessible by the employment of knife surgery. Oftentimes the surgeon encounters pathological conditions which he cannot contend with successfully, due to the liability of meeting with uncontrollable hemorrhage, either because the tissue is such that it will not retain ligatures or because sloughing following his operation may extend to neighboring blood vessels and produce troublesome and even dangerous secondary bleeding.

The procedure of electro-surgery, when used by the surgeon of proper training and experience, is readily controllable and entirely safe.

It is important in the treatment for destroying any lesion, particularly that of a malignant nature, that the first operation should completely remove or destroy the growth; otherwise we might stimulate new diseased cell activity.

Dr. George B. Eusterman and Dr. A. U. Desjardins of the Mayo Clinic have published some interesting reports concerning the value and importance of electro-surgery, particularly in the removal of accessible growths. Eusterman says, "Surgical diathermy is assuming greater importance in some clinics, especially in the removal of malignant and benign tumors of the face, skull, and oro-pharynx. Electro-coagulation is superior to the ordinary methods of cautery." Desjardins says, "The surgical application of diathermy is based on so concentrating the heat at one point as to produce tissue destruction. By means of suitable electrodes, such concentration and consequent destruction can be varied within fairly wide limits. Diathermy differs totally from cautery. In the former, the heat is not transmitted to the tissues by a hot instrument as is the case with the cautery. When the diathermic electrode is brought in certain relation to the tissues, the instrument remains cool, the heat being produced in the tissues themselves by their resistance to the passage of the electrical current."

The effects on body tissue when the high frequency electrical currents are used for its removal are ordinarily referred to as desiccation and coagulation, desiccation meaning the effect of drying or dehydration, this action being superficial, and coagulation meaning the deep destructive effect of the high frequency current. For the purpose of electro-surgery, apparatus should be used having a constant and consistent output of current of sufficient capacity and which will produce the required quality of spark of contact energy. The spark

gap which regulates the quality and indirectly the volume of the electrical discharge is a very important part of the apparatus.

Reference to the term "electro-coagulation" in this paper will mean the deep destruction or coagulation of tissue by the high frequency current in direct contact by means of the active electrode connected with one terminal in conjunction with the indifferent electrode connected with the other terminal of the high frequency machine and applied to any convenient part of the body. This constitutes a bi-terminal high frequency application with the damped wave characteristic. Its use is indicated for the removal of many forms of cancer which are external or accessible in cavities, also in treating deep seated growths after they are exposed by means of the ordinary surgical procedure. There is very little sloughing beyond the border of current contact and scarcely any pain or other disagreeable reaction following the treatment. Blood vessels and lymph channels are immediately sealed so that there is no blood loss and these possible entrances for the migration of disease cells are effectively shut off and closed.

In the operation for the removal of growths by electro-coagulation, the following technique is the one usually employed by the writer: A large indifferent metal electrode usually 8″ x 6″ or larger, is applied to some part of the body where good contact can be obtained as on the back below the angle of the scapula; general anaesthesia or local such as nerve blocking being used. The active electrode consisting of a surgical knife fitted in an insulated handle is used in contact with the tissue to be removed. The current is that delivered from a suitable high frequency apparatus of the d'Arsonval type, which will deliver a high milliamperage and remain constant in action. The current is turned on by an assistant, and gradually increased until coagulation occurs as shown by the cooked appearance of the tissue. The knife inserted just beyond and below the margin of the growth is then gradually moved through the circumference with a rotary motion, the growth being lifted, as it becomes separated, with the other hand by means of a suture imbedded in the structure or by forceps. This is continued until entire removal is accomplished. If conditions and technique are correct no bleeding results and a clean seared surface is assured. Very little if any pain follows, and a superficial slough occurs leaving healthy underlying tissue.

The method of electro-coagulation is adapted to the treatment of a great variety of lesions and growths in many parts of the body, and my interest has been particularly attracted to the good results obtained in the treatment of a number of cases similar to the following:

J. S. ———, age 80,—was operated on by the writer for removal of a papillary carcinoma at the base of the tongue about the size and thickness of an English walnut. The patient was anaesthetized with ether, a mouth gag being inserted; the tongue was held in position by a long suture passing through its center; the cheek was divided by a lateral incision extending from the angle of the mouth to a point midway to the angle of the jaw, thus exposing the growth, which was removed by cutting it away with a knife electrode according to

the method of electro-coagulation previously described. There was no bleeding, as all vessels were immediately closed off by the electrical energy as the operation proceeded. The surface left after removal was desiccated and the line of demarcation extended well beyond the diseased tissue. The absence of bleeding makes it much easier to visualize just what is taking place in the operative field, and we are thus able to perform our work with more accuracy. By this method we are better able to destroy malignant cells, which may be at some distance beyond the growth, thus diminishing any tendency to recurrence.

R. W.———aged 55,—was operated on by the writer three years ago for the removal of an extensive leucoplakia involving the cheek adjacent to the left lower jaw; this case had been previously treated by radium for one year with no result except that the disease was much aggravated, the patient suffering considerable pain after each application. The radium treatment in this case was given by a physician who was skilled and experienced in its use. The diseased tissue was removed by electro-coagulation; the indifferent metal electrode, size 8″ x 10″, was placed under the shoulders, and the surgical knife in an insulated handle was used as the active electrode; this was carried around the growth beyond its margin, the growth being gradually lifted from its bed as it was separated by the current contact. Sloughs covered all the coagulated area, which is usual, and these separated in about two weeks. During this time the patient was able to be about every day, had very little discomfort, required no narcotics, and had no blood loss during or after the operation. Up to the present time the area treated has held its full degree of improvement.

Malignant conditions involving the mucous membranes, as cancer of the tongue, leucoplakia, etc., usually respond very little, if at all, to treatment by x-ray or radium alone, whereas when electro-coagulation is used, the results are usually satisfactory. In coagulating tissue which is close to bony structures, care should be exercised not to coagulate deeply enough to destroy the periosteum, as it takes considerable time, even many months in some cases, for this to heal. The entire bony structure may be destroyed when necessary. Caution should also be exercised in all these treatments to see that the indifferent electrode closely approximates the skin surface; it should be held in place by a bandage, preferably of elastic material, so that if the patient moves it is not so easily dislodged. Very severe burning may result from loose or improper electrical contact, due to the arc formed in the air space between the electrode and the skin; good electrical contact, therefore, must be maintained throughout the entire operation.

Electro-coagulation, if properly performed, is not accompanied by surgical shock, hemorrhage, or any loss of blood during or after the operation. In treating growths in the mouth, sometimes the coagulation will not go beyond the point of actual contact, and it is well to watch these cases during the sloughing process so as to guard against possible bleeding when the slough begins to separate; this, however, will very seldom

occur. While the operation of electro-coagulation is going on, if any bleeding should take place, it may be immediately controlled by applying the active electrode to its source.

While the foot switch may be used by the operator, with which to turn the current on and off, it has the disadvantage of dividing the attention of the operator between his hands and his feet; also, when using the foot switch the current strength cannot be regulated, so that for the ordinary purposes of any electro-coagulation operation the aid of a good assistant stationed at the apparatus, who can quickly change the control switch of the transformer so that it will deliver a greater or less amount of current, changing at once when signalled by the operator, gives the most satisfactory results.

The operator may disregard any meter reading when using electrical currents to coagulate, as his best guide is his observation of the changes taking place, or, in other words, the reaction on the destroyed tissue. The amount and character of current used, together with the time needed for its application, must depend largely on knowledge gained from previous experience.

Electro-desiccation has the combined properties of shrinking and sterilizing all tissue with which it comes in contact and it may accomplish this without extensive destruction. Electro-desiccation is the method of choice in the treatment of small superficial skin lesions especially those which are elevated from the surface and for removing such hypertrophic conditions of the mucous membranes as polyps, tonsils and hemorrhoids. As this is a mono-terminal application, it may be used with absolute safety, is under the entire control of the operator, is followed by a minimum amount of slough, no after pain, and the tissues are dehydrated with a minimum amount of underlying trauma. In the treatment of diseased tonsils and hemorrhoids, the method of electro-desiccation is the one preferred when proper technique is employed. Many hundreds of cases of diseased tonsils during a period of eighteen years have been successfully treated by the writer according to the following technique: For convenience of application I have used an electrode devised by me especially for this work. I prefer a white spark, the so-called cold spark, instead of the red or flaming one. Crypts containing foreign substances are cleaned out before beginning treatment. The position of the patient should be upright in the chair facing the light, if direct light is used, or may be treated by artificial light reflected from a head mirror. No mouth gag is necessary. Swab the tonsils, pharynx, and uvula with equal parts of adrenalin 1 to 1000, and solution of cocaine 10 per cent. or any equally efficient anaesthetic. With the mouth wide open, keep the tongue out of the way with a wide glass or wooden tongue depressor; introduce the electrode so that its glass covering which projects from one quarter to one-half inch beyond its metal point, touches the tonsil; turn on previously tested current delivered from the Oudin terminal of a high frequency apparatus, then rapidly pass spark over tonsil surface until reaction occurs, as shown by a white film. The tonsillar tissue should not be penetrated by the electrode used. In

nervous patients we may have to quickly withdraw the electrode, if gagging occurs, then go back and repeat. In most cases, both tonsils may be treated at one sitting. A slight irritation of the throat is felt for one or two days; in a period varying from five to seven days the throat will be found clear, and similar treatment is then given at these intervals until the maximum result is secured, usually in about six weeks, according to the amount of hypertrophy present. The length of the spark used varies in different cases and individual judgment must be exercised.

In the treatment of hemorrhoids and polyps, the application of the current is somewhat similar except that we usually bring the active electrode in direct contact with the tissue to be removed, the pile tumor or polyp having previously been clamped. Very little after-care is necessary and these patients are able to resume their accustomed activities on the completion of the operation.

Electro-desiccation of tissue may be produced either by the bombardment of the spark of various lengths or by the direct contact of the metallic electrode inserted into the tissue, although when direct contact is made the resulting action or destruction is more properly coagulation.

The use of the so-called cutting current of high frequency for removing a growth after the entire mass has been coagulated may have a slight time saving advantage and seems to be well adapted for the purpose of rapid dissection of tissue, but unless one is particularly well skilled in its use the amount of destruction may be more than is desired, for it must be passed through the tissue very rapidly and its action is not so readily controlled as is that of the technique heretofore described.

Professor W. T. Bovie of Harvard University has experimented with an unique outfit for producing the combined effects of the coagulating and cutting currents and has done some very creditable research work tending toward the solution of an accurate measurement of the electrical energy necessary to destroy the various bodily tissues. When this is accomplished, we may then be able to select the particular quality and quantity of current adapted to the condition to be treated.

Every credit for the development of the use of high frequency currents in the field of surgery in this country is due Dr. William L. Clarke of Philadelphia who was among the first to call attention to the value of these currents in surgery.

The title of this paper, "Electro-Surgery," is used with the hope that it may call attention to the importance of a terminology that has a definite meaning in this specialized work, embracing as it does the use of electricity as an additional agent of value to the use of the scalpel in the field of surgery.

The best results, particularly in the treatment of inaccessible growths, will be obtained by the joint efforts of the surgeon skilled in the knowledge and use of knife surgery, and the surgeon having similar knowledge of the use and action of electricity in a surgical sense.

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ELECTROSURGERY

A BRIEF REVIEW OF ITS ADVENT AND SOME OF ITS USES

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Electrosurgery came on the surgical horizon about 1907 as an outcome of the epoch making experiments of d'Arsonval and Oudin. The present efficient form of electrosurgery in this country, and largely in the world, is due to Wiiliam L. Clark of Philadelphia, who took it over in a crude state and brought it to the borders of perfection. Addenda have been large due to technical developments by electrical specialists, responding to stated needs of surgeons.

De Keating Hart and Pozzi over twenty years ago used a long sparking current of high voltage and low amperage for the destruction of tumors, called fulguration Edwin Beer [1] of New York took this up about 1908 and used it extensively in bladder tumors. The difficulty with this agent was a lack of penetration; Beer's work, however, was distinctly prophetic of all that has followed.

The demand for electrosurgery arose from imperfections in the established surgical technic, long accepted as inherent in operative methods and, therefore, hardly realized until the new agent and the acquired facility necessary to its skilful application appeared to remedy them.

The reproaches indicated have lain in the prolongation of operations due to the application of ligatures to stop hemorrhage; in the liabiiity of conveying infection or of distributing it in the general course of many operations; in the fact that ligatures acting as foreign bodies may become foci of infection; in the deplorable manipulations of tissues; in the contamination of wounds and general messiness of handling malignant growths and chronic and subacute infections; in the limitations often imposed on our extirpative work by reason of the depth of the operation from the surface, particularly in the oral and nasal cavities, in neural surgery, and in rectal and sometimes in abdominal procedures; in the fact that any serious difficulty of ligation in sharp hemorrhage in a deep operation often precludes a satisfactory continuation to its completion; in the condition of tissues after recovery, which makes a desirable

1. Beer, Edwin: Removal of Neoplasms of the Urinary Bladder, J. A. M. A. 54: 1768 (May 28) 1910.

secondary operation objectionable; in shock arising from prolonged operation with attendant hemorrhage. Experience has shown that these objections are in a measure overcome by electrosurgery.

Electrosurgery as now used is the employment of a high frequency alternating electric current of about 1,000,000 to 2,000,000 or more oscillations per second for the destruction or excision of diseased tissues. The current voltage and amperage under perfect control ranges from a minute, almost invisible, spark up to a heavy flashing flame, causing a necrobiotic heat penetration to the depth of 1 cm. on all sides of the electrode The current is applied by "active" electrodes of various shapes: needle, thin narrow blade, ball, curet, wire loop.

These currents are applied through a uniterminal or biterminal connection with the generating apparatus, affording either a desiccation or a dehydration of the tissues, an electrocoagulation, or, by molecular disintegration, a cleavage or cutting of tissues.

The cardinal virtues of electrosurgery lie in effective destruction in loco of tissues that it is desirable to eliminate. This manifestly includes all forms of malignancy. There is no handling of tissues because of the knife and fork type of operation, which is unequaled in cleanliness by the immediate complete sterilization of both bacterial and malignant infection.

Hemostasis is easily effected in severing vessels up to about 1 mm. in diameter either by the application of the coagulating electrode direct or by the intermediary of a well-pointed hemostatic clamp, isolating the vessel. Thus ligatures are avoided, and the risk of infection is lessened by reason of the reduction of the imported foreign material. The ability to check hemorrhage, keeping the fingers away from the wound, makes it possible to continue deep work in various parts of the body.

Another advantage is the extended use of local anesthesia, which reduces hospitalization by making a number of these patients ambulatory.

A notable achievement lies in the group of operations being undertaken, many of them until recently hardly possible, particularly extensive malignant growths of the jaw, oral cavity, antra, brain, breast, thyroid, and vulva, resulting in a great number of patients with open wounds which, being kept clean, heal rapidly without pain or toxemia and yield a soft, pliable scar. Tonsillectomies in patients presenting contraindications for ordinary surgical procedure, such as cardiac disease and advanced age, are now being performed electrosurgically by trained operators. The destruction of the tonsil is effected in several stages, by applying the current alternately first to one side and then to the other, at intervals of one or two weeks. Such patients are usually ambulatory. The pillars must be kept from adhering by scar tissue until all infection disappears, thus avoiding encapsulation of infectious material. The method is still considered to be appli-

cable only in selected cases and by men especially trained both in electrotherapy and otolaryngology.

Those unfamiliar with the intensity of the high frequency currents and their depth of penetration may easily strike destruction into deep-seated structures adjacent to the disease areas. Especially is this true of blood vessels (a carotid, for example) leading to and from the part or traversing neighboring tissues. To prevent hemorrhage at the operation or subsequently when the coagulum sloughs away, a ligation of tributary vessels is often advisable. While muscles (the pectoral, for example) are being incised, the faradic effect may be sufficient to cause muscular jerkings lively enough to throw the electrode against a neighboring large vessel. Severance of nerves often causes the same muscular contraction in the muscles supplied, with dangerous possibilities.

Another pitfall is that of undertreatment, particularly in the hands of an amateur. The extreme limits of the disease must always be estimated in malignant conditions and the destruction and the extirpation carried well out into the normal zone. The electrosurgical aspirant should first acquire a good general surgical training, adding later to his technic the use of the high frequency electric currents. A mere novice has no more right to exploit this new adjuvant than has the first year medical student to prescribe digitalis.

Various forms of apparatus have been developed through the years to such an extent that at present the market is replete with many new instruments, some of them only fairly satisfactory. Research jointly by surgeon and physicist, together with the competitive spirit of a group of able manufacturers continually improving their products, has accomplished much in developing a number of admirable, perfect instruments. Two general types are available: The one, dating from the original experiments of d'Arsonval and others, employs a transformer, a series of condensers, spark gaps and an Oudin coil as the source of power; the other, beginning with the discoveries of de Forest, employs one or more triode vacuum tubes as the generating factor. Each surgeon will learn to choose for himself, after thorough trial, the type best adapted to his needs. The better machines furnish a current readily available by the easy manipulation of a comprehensible switchboard or the ready change of electrodes.

The perfect generator should produce a smooth current without faradic effect, varying from the finest desiccation spark to heavy coagulation without much flashing or uncontrollable flame. Efficient coagulation by a blunt or ball electrode brought near to the tissues, with the minimal visible sparking, is another criterion of a perfect current. There ought not to be any fusion of coagulated tissues to the electrode, but to date no material is available out of which electrodes can be made which will not stick to the tissues, pulling some away when removed and risking tearing a vessel. In

addition, the cutting current should be regulable from one severing tissue with only 0.1 mm. of destruction on each side to one coagulating 1 or 2 mm. in depth. The fine cutting current permits primary union; the heavier cutting current used in excising an extensive ulcerative malignant growth leaves in situ a dry sterile coagulum, which prevents any local recurrence or the dissemination of cells spilled from the ulcer. In the latter class, the local defects are so great that primary union is not anticipated and the coagulum becomes a desideratum. All these features, characterizing the perfect machine with the minimum number of controls, should be available at the operating table through a proper foot switch or by sterile connections for the operator's immediate control, without calling for an extra assistant.

At present, electrosurgical cutting and coagulation are accomplished by separate electrodes, usually of different shape, either necessitating two connections with the machine or an interchange of electrodes in a common handle attached by a single wire to the apparatus. In the latter instance an extra assistant is needed to switch from cutting to coagulating current or vice versa. Two wires, used to carry the current, form an awkward addendum at an already complicated operating table. In operating rooms, where inflammable anesthetics are used, surgeons are urged to secure apparatus of the best construction and to keep it in good repair, because open or static electric sparks may cause serious explosions.[2] As time passes, it is hoped that these and other technical problems will be simplified.

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2. Death from Explosion of Anesthetic Gases, editorial, J. A. M. A. **96:** 530 (Feb. 13) 1932.

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